An overview on (Mathematical) Plant Growth Modelling and Applications

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Plants are very complex systems. If agronomic plants, like rice, maize or corn, are essential to provide food or other kind of goods, trees are also essential to preserve the carbon balance, or even to absorb carbon surplus. Despite the great importance of plants, only a small number of modellers, and applied mathematicians are involved in the modelling, the development of mathematical tools, the simulation of plant growth, and, in general, in problems related to Agronomy or Forestry. In fact, the amount of knowledges necessary to understand how a plant is growing is huge and only a multidisciplinary approach can be used to overcome the encountered difficulties. Phenomena are so complex, that even botanist, agronomists and foresters still debate how to handle them efficiently in plant growth models, and, more important, what are the essential ingredients to take into account to obtain a realistic modeling. Indeed, if we know very precisely what is going on in photosynthesis, transpiration processes,..., we didn't yet succeed in the development of macroscopic laws, like in Physics or in Mechanics. Plant growth modelling is not only challenging from the scientific point of view, but is also crucial for real applications, like, for instance, improving crop yields, developing biological tools against Pest attacks, studying the impact of climate change, time evolution of rain forests,.... Thus not only plant growth modeling is challenging but its interactions with the environment too.

Up to now people have used different modeling for plant growth, like empirical models, geometric models, process-based models or functional and structural plant models [7].... AMAP laboratory (Bot**A**ny and co**M**putation**A**l **P**lant architecture) is a place where Botany, Ecophysiology, Plant Architecture, Applied Mathematics, and Computer Science are deeply connected [1]. AMAP has become World leader in Botany, in Plant Architecture [3], and, based on biological knowledges, has developed several Simulation tools, like AMAPsim: (see [2] for an overview)

Figure 1: A palm tree and a sunflower powered by AMAPsim

The aim of this lecture is to show the diversity of the problems encountered in the area of plant growth modeling, through an overview on different ongoing studies in AMAP. After a brief recall on some "basic" knowledges' in Botany and in Ecophysiology, I will present different problems related to plant growth, root growth [4, 5], biomechanics [6], ecology, ... using discrete or continuous models. The wide diversity of problems encountered leads to very interresting mathematical problems, that deserve theoretical and numerical investigations.

CIRAD is an International Centre of Agronomic Research for Developing Countries. It is based in Montpellier (France). About 800 researchers, around the world, are working in life sciences, social sciences and engineering sciences, applied to agriculture, food and rural territories.

References

[1] AMAP: http://amap.cirad.fr

[2] J.-F. Barczi, H. Rey, Y. Caraglio, P. de Reffye, D. Barthélémy, Q. Dong, T. Fourcaud. AMAPsim: an integrative whole-plant architecture simulator based on botanical knowledge. Annals of Botany, **101** (8) (2008), 1125-1138

[3] D. Barthélémy, Y. Caraglio. Plant Architecture: A Dynamic, Multilevel and Comprehensive Approach to Plant Form, Structure and Ontogeny. Annals of Botany, **99** (3) (2007), 315-348.

[4] A. Bonneu, Y. Dumont, H. Rey, C. Jourdan, and T. Fourcaud, Splitting advection, diffusion and reaction processes in a continuous model of root growth, FSPM 2010, UC Davis, USA.

[5] A. Bonneu, Y. Dumont, H. Rey, C. Jourdan, and T. Fourcaud, Biological significance of an advection diffusion reaction model for simulating root system growth and development, submitted.

[6] T. Guillon, Y. Dumont, and T. Fourcaud, A new framework for modeling surface growth and biomechanics in beam theory, submitted.

[7] P. de Reffye, E. Heuvelink,Y. Guo,B.G. Zhang,and B.G. Hu, Coupling process based models and plant architectural models: a key issue in simulating crop production. In White, J. W., Cao, W., Wang, E. (Eds) Crop Modeling and Decision Support. Nanjing : Springer (2009), 130-147.